Mapping the Woody Component of Rangeland Vegetation using Landsat Satellite Data, Ngamiland, Botswana

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Abstract

This article evaluates the use of the Landsat Multispectral Sensor System (MSS) as a tool for mapping the woody component of rangeland vegetation. The study area consists of a zone of low tree and shrub savanna along the southern margin of the Okavango Delta, Ngamiland, Botswana. Relationships between reflectance data recorded by the Landsat system and percentage woody cover were analysed. The results were used to produce maps showing the extent of various classes of percentage woody cover.

Introduction

Cattle production has traditionally held a key position both economically and socially in Botswana. Therefore, the role of rangeland as a national resource is of major importance. In the Ngamiland District a major contribution to the economy is derived from cattle production (Min. of Agriculture, 1976). The main zone of livestock production in Ngamiland is the southeast margin of the Okavango Delta — including the Lake Ngami basin (Fig 1). Other areas are of limited importance due either to remoteness or the presence of tsetse flies.

A number of vegetation types are utilized for cattle production within the region — including grasslands on seasonal floodplains *(melapo)*, woodlands and savanna types. One of the most important types used is the low tree and shrub savanna which is dominant along the south eastern margin of the delta. The terrain is gently undulating, composed of old stabilised dunes. The soils are sandy and existed between total vegetation cover and MSS band 7 (near infrared: 0.8 to 1.1um).

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This study aims to determine whether such relationships exist for green woody vegetation cover in the Ngamiland area. Ground reference data collection was undertaken in 1983, at the beginning of the winter low rainfall period (April to June). This provided optimal conditions for the study, with woody vegetation remaining in leaf, while ground layer vegetation was almost absent (restricted to places beneath thick thorn bush cover, where it was protected from cattle). The study period also coincided with an aerial survey of the region commissioned by the Botswana Government.

Woody cover and Landsat MSS reflectance data

Initially 49 sample sites were located on a Landsat image (7 May 1983) of the study area. The sites consisted of blocks of four Landsat picture elements or 'pixels' (the basic unit of resolution) with a total nominal ground area of 158m x 134m. The reflectance values for each of the pixel groups was noted (in all four MSS bands). Values were also derived for a number of arithmetic manipulations of the image data; for example, Principal Components Analysis (PCA).

The reflectance data was then compared with woody cover values obtained from aerial photographs for each site. Percentage values for the total tree and shrub cover were obtained from 'point counts' using a 0,2 mm grid overlaid on unstructured sand, generally pale brown to white in colour. A mixture of *Acacia* and *Grewia* trees and shrubs dominate the sand ridges and level areas between the depressions. The depressions are generally dominated by *Acacias*, while the tree *Terminalia sericea* may become locally dominant on the ridge slopes.

The importance of woody vegetation to range-

land quality in Botswana has been documented: bush encroachment (e.g. Van Rensburg, 1971: APRU, 1975), browse (e.g. APRU, 1975 and 1980), and shade provision (e.g. APRU, 1980: Timberlake, 1980). Therefore, the ability to map variations in the amount and type of woody cover would provide a useful aid to range management. Little attempt has been made to use satellite data for this purpose in Africa, Lane (1982), working in Tanzania, attempted to identify relationships between woody cover and Landsat MSS data but with little success. Griffiths and Collins (1983), were more successful. They were able to show that a significant relationship existed between the amount of non-green woody vegetation of an area in Kenya, and reflectance levels. A negative correlation ($r = -0,61$) was found between woody cover and values in MSS band 5 (visible red light: 0,6 to 0,7 um); the result, it was suggested, of masking of high reflectance from the soils beneath the canopy cover. In Botswana, Ringrose and Matheson (1986) have shown that a significant positive relationship ($r = 0,475$) exists between total vegetation cover and MSS band 5, for an area of Hardveld vegetation near Gaborone. They also showed thar a negative relationship ($r = -0,777$ on 1:50 000 scale black and white serial photographs. A grid representing 200 m x 200 m on the ground was used to take into account relocation error. The cover measurement was expressed as a percentage of the total number of points which occurred over woody canopy. Aerial photography, (1:10 000, colour) and ground reference data were used to check the accuracy of the measurements.

Correlation and regression analysis were used to test for any relationships between the Landsat data and woody cover values. A number of strong, significant relationships were established (Table 1). The strongest relationships occurred between the single MSS band values and cover. All of these showed a strong negative correlation (Table 1 shows these in rank order of strength of the relationships). These results suggest a similar situation to that identified by Griffiths and Collins (1983) for non-green cover, with woody canopy acting as a mask against higher reflectances from exposed soil surfaces. Allen and Richards (1983) note that soils of semi-arid areas are often highly reflective, in contrast to those of humid areas, due to their low moisture contents: reflectance from soils may be higher than those from green vegetation, even in the near infrared wavelengths. The soils of the study area were characteristically very light in colour and extremely well drained. Variations in structure of the woody vegetation and of species composition did not appear to have a significant affect on the relationships. A comparison of the reflectance characteristics of Colophospermum mopane shrubland and woodland in the Ngamiland District (Vujakovic, 1985) also indicated that vegetation structure was unimportant. MSS band 5 (the MSS band with the strongest relationship with cover) records reflectances in the section of the electromagnetic spectrum which includes the peak of chlorophyll absorption (about 0,65 um). This would enhance the contrast between woody canopy and soil reflectance levels.

Mapping woody cover

A regression line was fitted to the bivariate data sets and the equation of the line was used to predict the MSS value corresponding to the particular values for percentage woody cover (Fig 2). This was used as the basis for generating classified images of parts of the study area using DIAD, a digital image processing system (Nigel Press Assoc., U.K.). Actual and predicted values for a number of sample sites are shown in Figure 3. At 86% green canopy cover the resultant spectral response curve is characteristic of a "typical" green leaf reflectance curve, while that for 6% cover has a curve more typical of soil. Soil curves tend to be similar in shape, even with large variations in soil type, varying mainly in the amplitude of the curve (amplitude being affected by factors such as texture, colour, moisture and organic matter (Hoffer, 1978)). The actual and predicted curves tend to confirm the idea that the relationships are dependent on the ratio of exposed soil to canopy cover.

The regression equation for MSS band 5 with woody cover was selected to generate a classified image (Fig 2). Band 5 values corresponding to selected class ranges of percentage woody cover (100-80%, 79-60%, 59-40%, 39-20% and 19-0%) were used to classify a selected sub-scene of the Landsat image (512 x 512 pixels). All pixels within a selected class were digitally colour coded (by "density slicing") to produce a classified map. A preliminary assessment of accuracy was obtained by analysing the classification of the 49 sample sites. This produced a classification accuracy of 79,5%. The same test was applied to the second and third ranking relationships (see Table 2). A further 20 pixel blocks were sampled from the classified image and compared with cover values obtained from the aerial photographs. These produced a classification accuracy of 80%. Table 3 shows the combined 69 sample sites in terms of their seperation in classification feature space. The data from the additional 20 samples had no practical affect on the regression equation as used in the classification.

The method described above was used to produce a more detailed classification of woody cover for a government research ranch run by the Animal Production Research Unit (APRU). Detailed ground reference data was obtained during the 1983 field season and 1:10 000 scale photography was available for the ranch. Using 10% interval classes, a classified map was generated. Forty five pixel groups were subsequently sampled and compared

with cover values derived from the large scale photographs. At the 10% interval classification the level of accuracy still remained relatively high at 75,6% (Table 4).

Discussion

It appears that a strong relationship does exist between reflectance values (MSS) and cover of green woody vegetation within the low tree and shrub savanna of Ngamiland. These relationships can be used to generate classified images or maps of the spatial variation of woody cover from the digital Landsat data. This provides a more rapid and practical method of mapping than is possible from visual analysis of aerial photographs or ground surveys only. The levels of accuracy obtained for the classifications are thought to be adequate, especially when consideration is given to the nature of the terrain investigated and the limitations of any other methods. The method might also be adapted to monitor change as well as the static situation, for example, to monitor bush encroachment or changes in fuel wood resources.

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TABLE 1

Relationship between percentage woody cover (x) and Landsat reflectance values (y)

The Landsat reflectance values (y) are ranked in descending order on the basis of their calculated correlation coefficient with values for percentage woody cover. All figures based on 49 sample sites.

Rank	Variable (y)	corr. coefficient (r)	Standard error of estimate
1	MMS 5	— 0,94157 *	7,12
2	MSS 4	— 0,93249 *	4,61
3	1st Principal component	— 0,93217 *	5,25
4	MSS 7	— 0,92194 *	5,10
5	MSS 6	— 0,01805 *	6,46
6	MSS 7 + MSS 5	— 0.90790 *	14,46
7	MSS 7 — MSS 5	— 0,88400 *	4,31
8	MSS7 + MSS5/MSS7 — MSS5	— 0,84822 *	3,56
9	MSS 7 / MSS 5	+ 0,84433 *	6,08
10	MSS) — MSS5/MSS7 + MSS5	+ 0,82896 *	3,91
11	2nd Principal component	+ 0,21875	13,56
12	3rd Principal component	+ 0,13998	1,21

* = significant at the 99,9% level

TABLE 2

Overall accuracy of classifications of percentage woody cover

Classification (Landsat variable)	No. of sites correctly classified	% currency of classification
MSS band 4	33	67,3
MSS band 5	39	79,5
First P.C.	36	73,5

$$\text{Overall accuracy} = \frac{\text{No. of correctly classified sites}}{\text{Total No. of sites}} \times 100$$

TABLE 3

Accuracy of the classification of woody cover based on Landsat MSS band 5 data

Class pixel was assigned to in feature space (Percentage woody cover)

	80%	79-60%	59-40%	39-20%	19%	Errors of ommission
100-80%	0	2	0	0	0	2
79-60%	0	12	3	0	0	3
59-40%	0	1	6	1	0	2
39-20%	0	0	4	17	1	5
19-00%	0	0	0	2	21	2
Errors of commission	0	3	7	3	1	**55

$$\text{Overall accuracy} = \frac{55}{69} \times 100\% = 79{,}7\%$$

**Sum of the principal diagonal

TABLE 4

Accuracy of the classification of woody cover (Tsetseku area sub-scene. 10% interval classes)

Class pixel is assigned to in feature space (percentage woody cover)

	59-50%	49-40%	39-30%	29-20%	19-10%	9-0%	Errors of omission
59-50%	5	1	1	0	0	0	2
49-40%	0	6	3	1	0	0	4
39-30%	0	2	9	1	0	0	3
29-20%	0	0	1	7	0	0	1
19-10%	0	0	0	1	3	0	1
09-00%	0	0	0	0	0	4	0
Errors of commission	0	3	5	3	0	0	**34

$$\text{Overall accuracy} = \frac{34}{45} \times 100 = 75{,}6\%$$

**Sum of the principal diagonal **

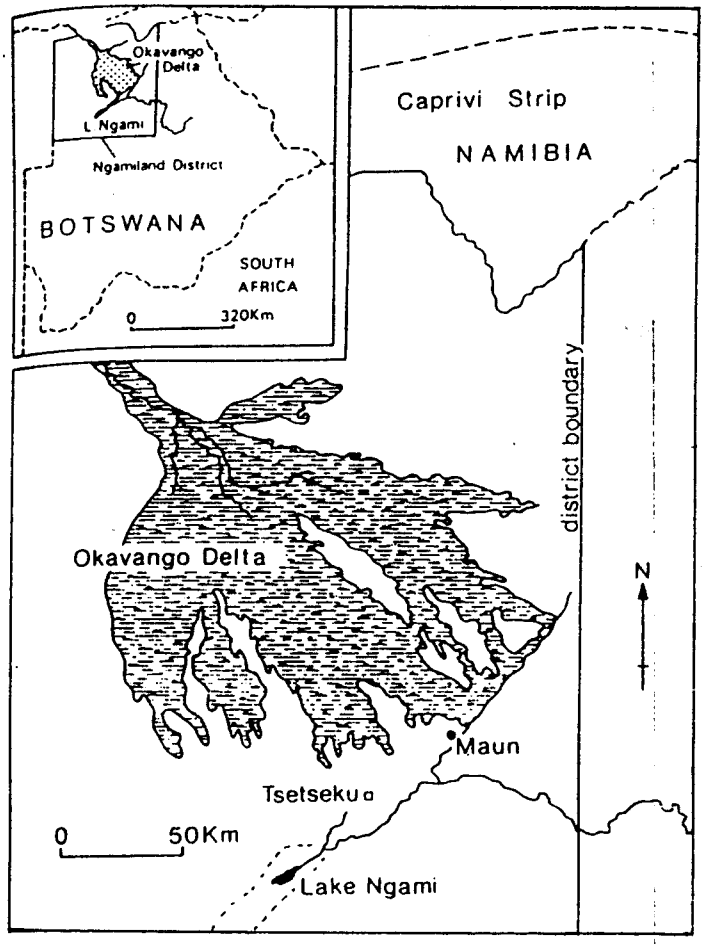

FIGURE 1 The Okavango Delta

FIGURE 3
Spectral response curves for various?

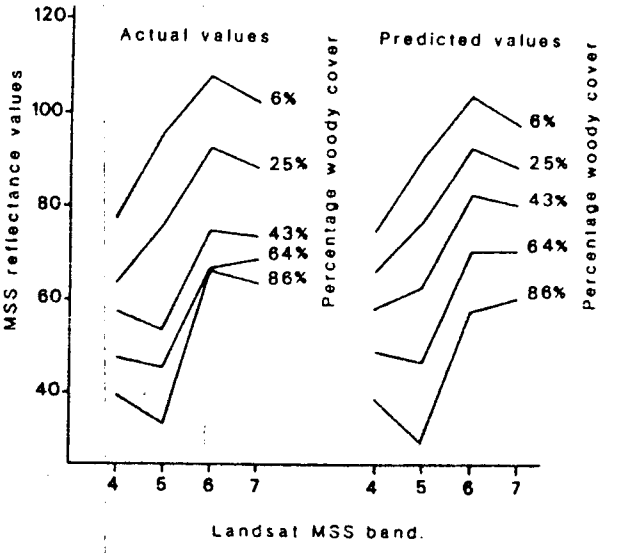

FIGURE 2
Scatter diagram showing the relationship between percentage woody cover and MSS band 5 years.